

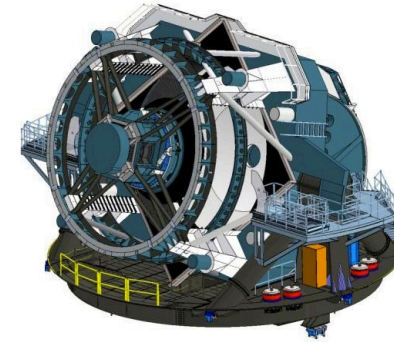
LSST

Large Synoptic Survey Telescope

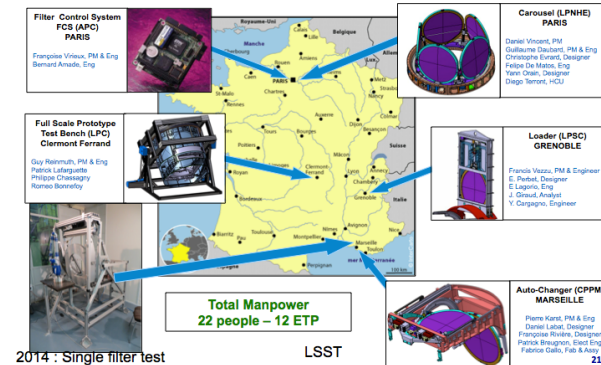
Jean-stephane Ricol
Aurélien Barrau
Adeline Choyer
LPSC

Outline

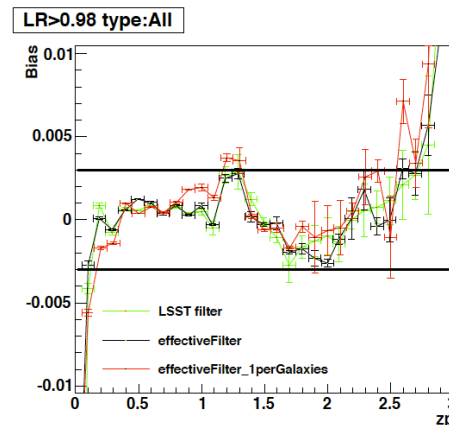
- Overview of the project (JSR)
- LSST science (JSR)



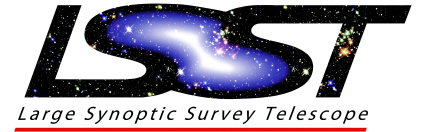
- LSST in France (A. Barrau)



- BAO (A. Choyer)
- PhotoZ (A. Choyer)



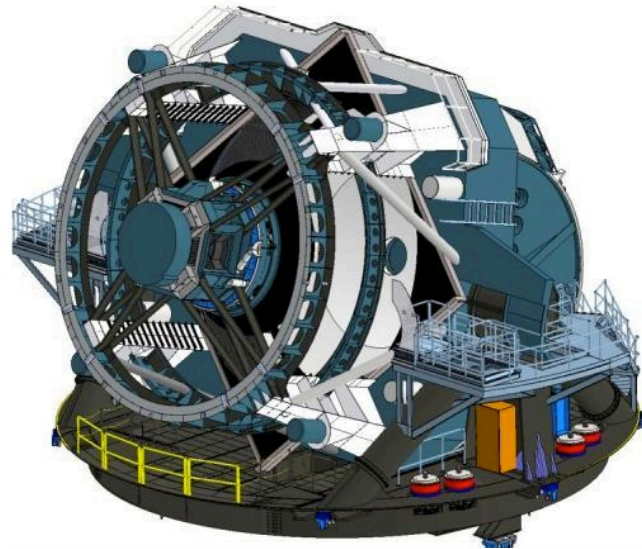
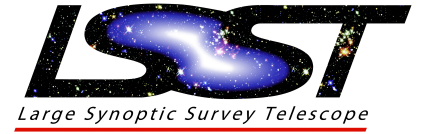
LSST : 3D movie of the sky



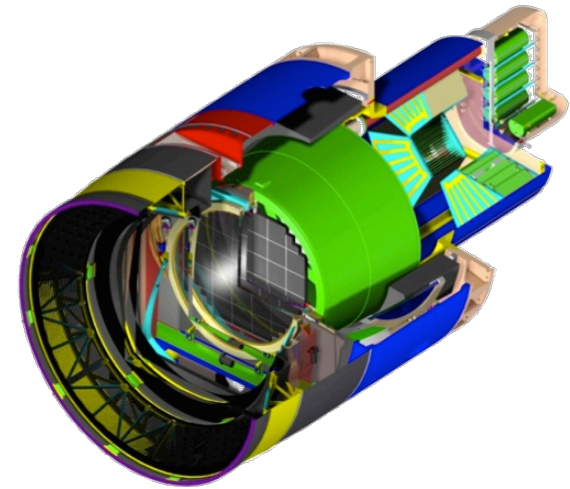
“Large Synoptic Survey Telescope”

- Derived from the Greek words $\sigma\acute{\upsilon}\nu$ (syn "together") and $\acute{\omicron}\psi\iota\varsigma$ (opsis "view")
- Wide, deep, fast
- Image of the entire visible sky every few nights : 3D (2D+z) movie of the sky
- Key field of LSST is Dark Energy constraints through statistical studies of shapes and distributions of 10s billions of galaxies + 100,000s of Type Ia supernovae at different epochs : expansion history of the Universe.
- Success of the project comes from the enormous variety of complementary scientific investigations : searches for small bodies in the solar system, precision astrometry of the outer regions of the Milky Way, transient phenomena ...

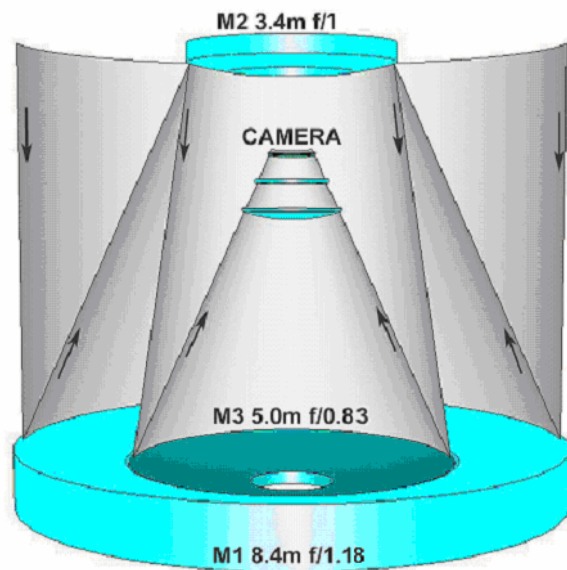
LSST System



Ground-based
8.4 m telescope



Wide Field Camera



Wide Field of View \Rightarrow 3-mirrors
modified Paul-Baker scheme (f/1.234)

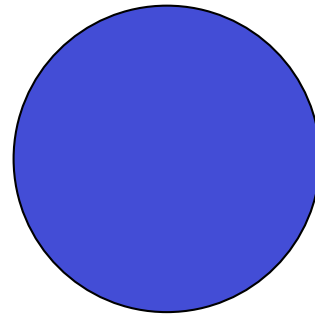
Étendue = observation power

Primary mirror diameter

Field of View
(Full Moon = 0.5 deg)



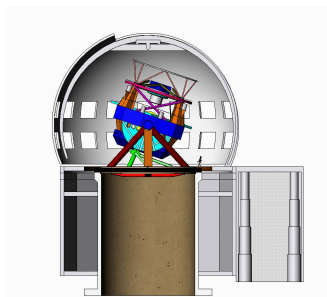
Keck (Hawaii)



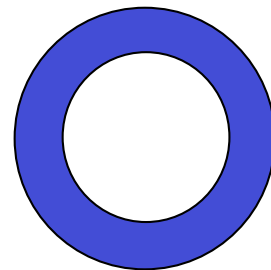
10 m



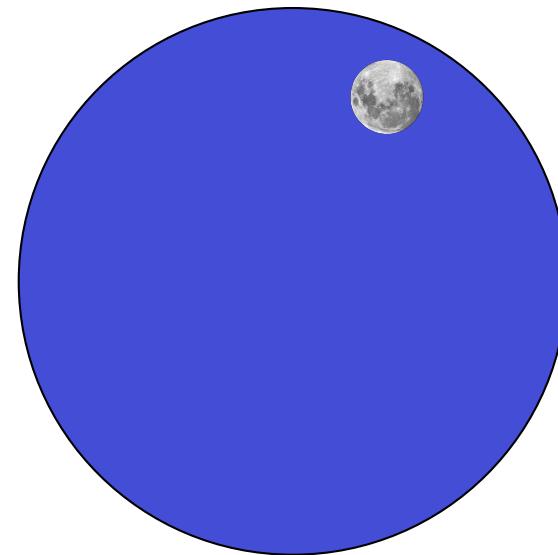
0.2 deg



LSST



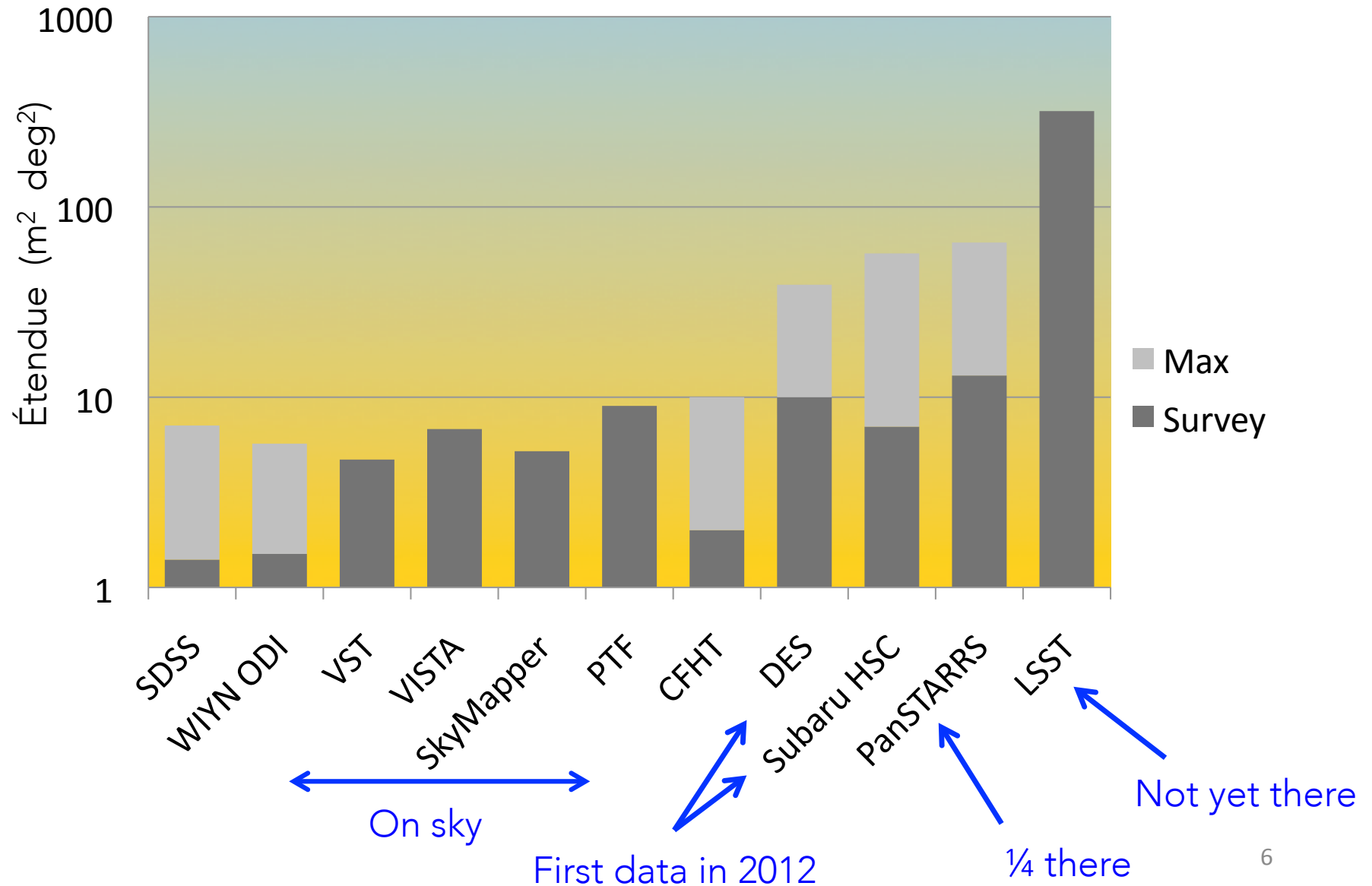
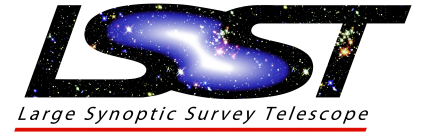
8.4 m



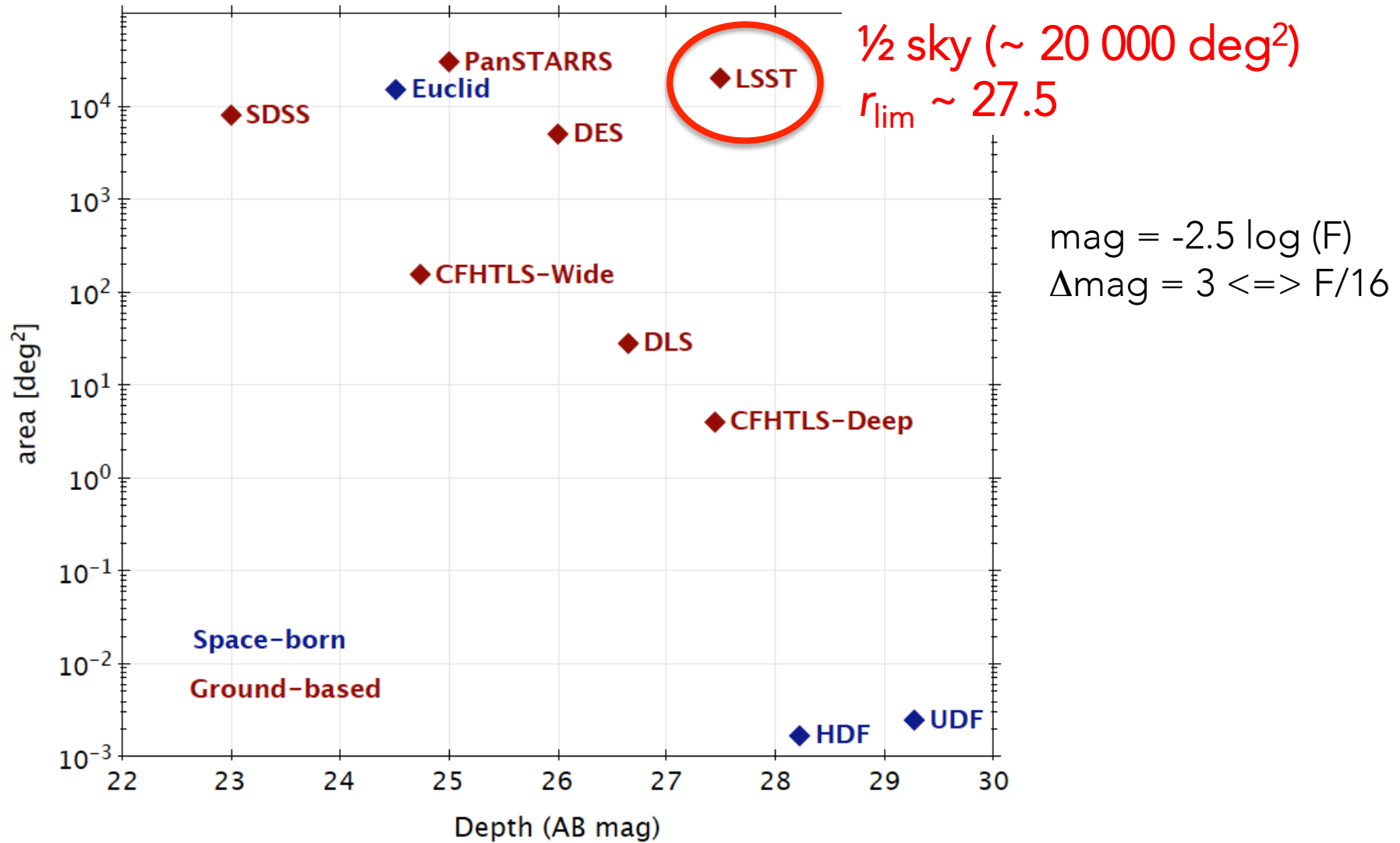
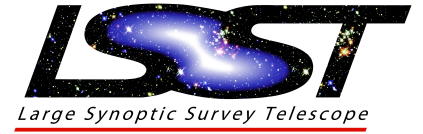
3.5 deg

Étendue	=	Mirror Surface	×	Field of view
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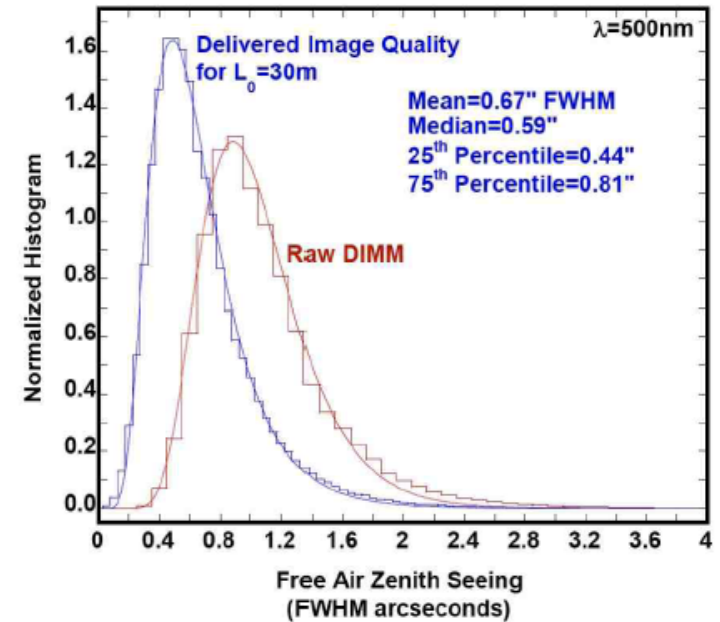
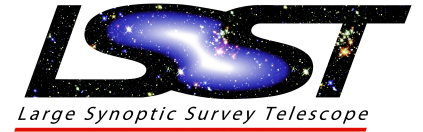
One Order of Magnitude "Bigger" System



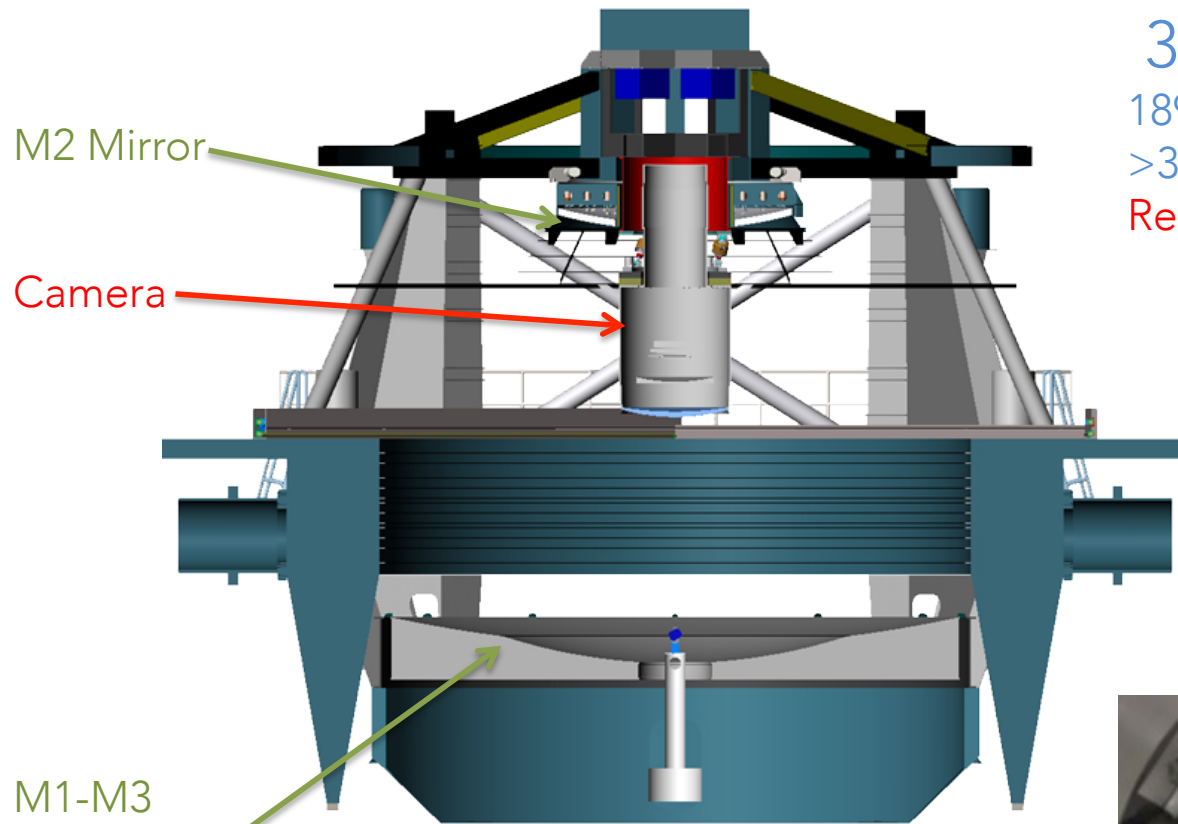
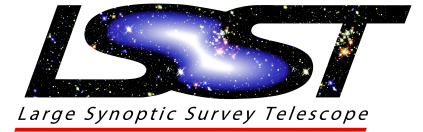
Deep and Wide Survey



LSST Location



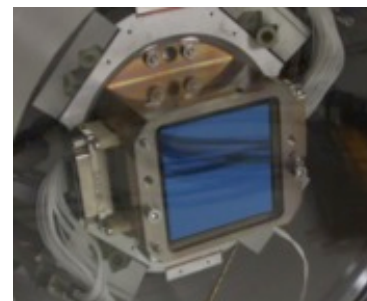
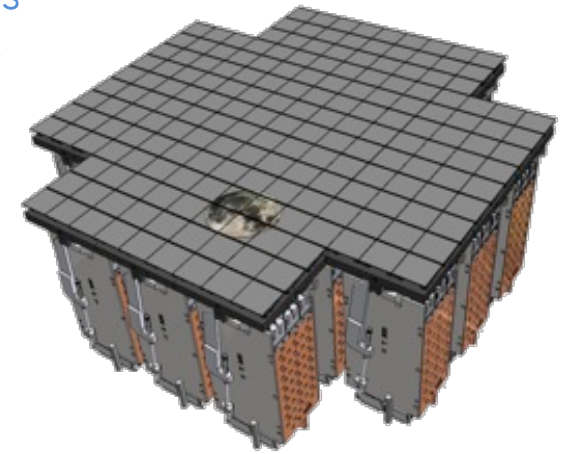
Deep, Wide and Fast = Challenging!



M1-M3
Primary
(8.4m) &
Tertiary
Mirrors

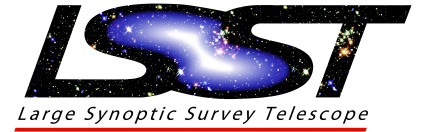
Moving Structure 300 tons

Field of view :
3.5 deg (9.6 deg²)
189 CCD (21 rafts)
>3·10⁹ pixels
Readout: 2s

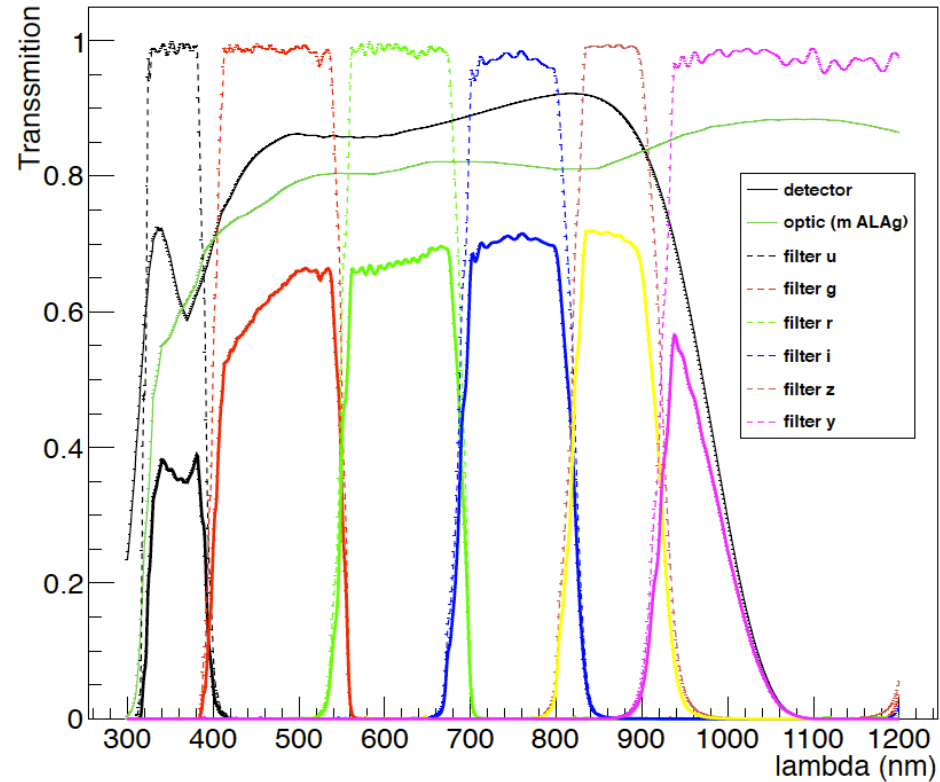


E2v CCD 250
4kx4k , 10 μm pixels
100 μm deep depleted
UV to IR sensitive
16 channels output
Designed by Dedicated
R&D for LSST

Photometry 6 bands



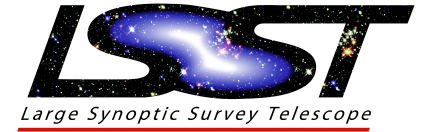
6-band : ugrizy 320–1070 nm



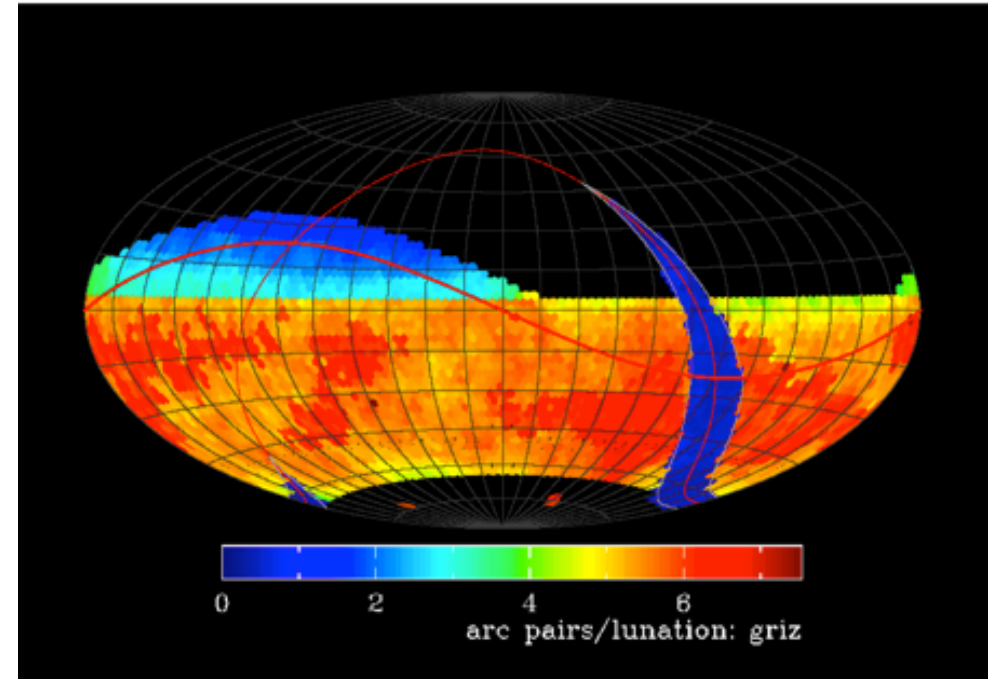
Visits per filter and mag limits

	u	g	r	i	z	y
Nb Visit	70	100	230	230	200	200
1 visit	23.9	25.0	24.7	24.0	23.3	22.1
10 year	26.1	27.4	27.5	26.8	26.1	24.9

Strategy: single observation plan



Survey(s) Area (with 0.2 arcsec / pixel)
Main : 18,000 square degrees to a uniform depth
Total : 25,000 square degrees (equatorial spur/asteroid + southern galactic cap / Magellanic clouds)



More than $2.75 \cdot 10^6$ visits (x 2 exposures)

1 visit = 15 s pose + 1 s shutter + 2 s read + 15 s pose + 1 s shutter + 5 s new pointing as reading

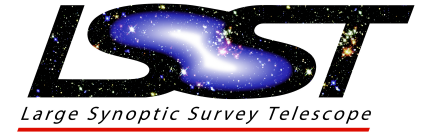
➔ Points to new positions in sky every 39 seconds

Number of visits per night : ~ 1000

Revisit after 30-60 minutes

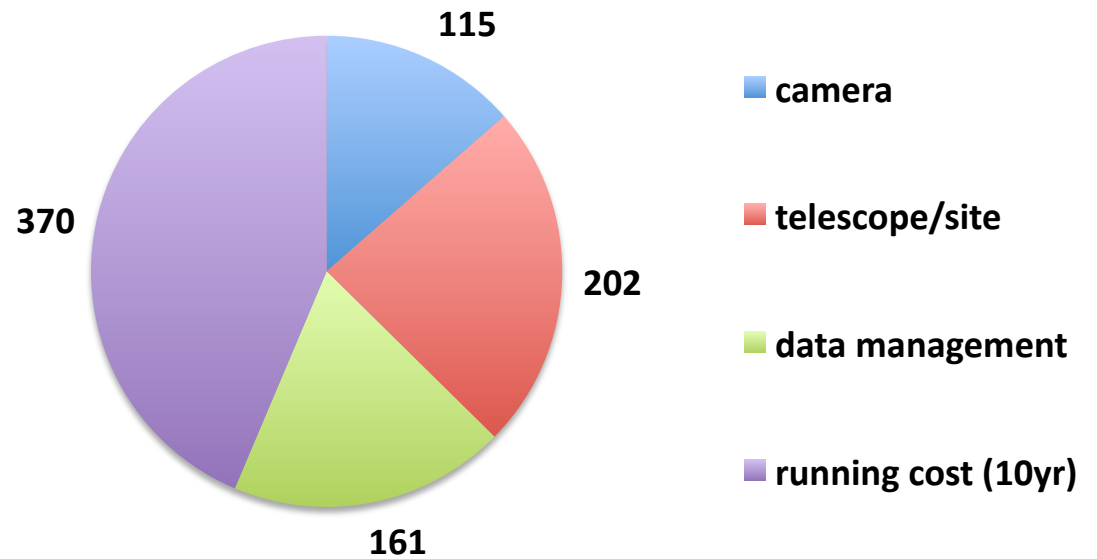
Visit pairs every 4 nights : movie of the sky

Planning / Cost / Data



- 2008-2014: R&D
- 2014-2017: Construction
- 2019: First Light
- 2020-2030: Observations

LSST Budget (total 848 M\$)



Data management :

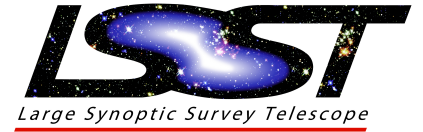
13 GB every 40 seconds = 330 MB/sec = 13 TB/night

~ 7 millions images after 10 years

Final data = 60 PB

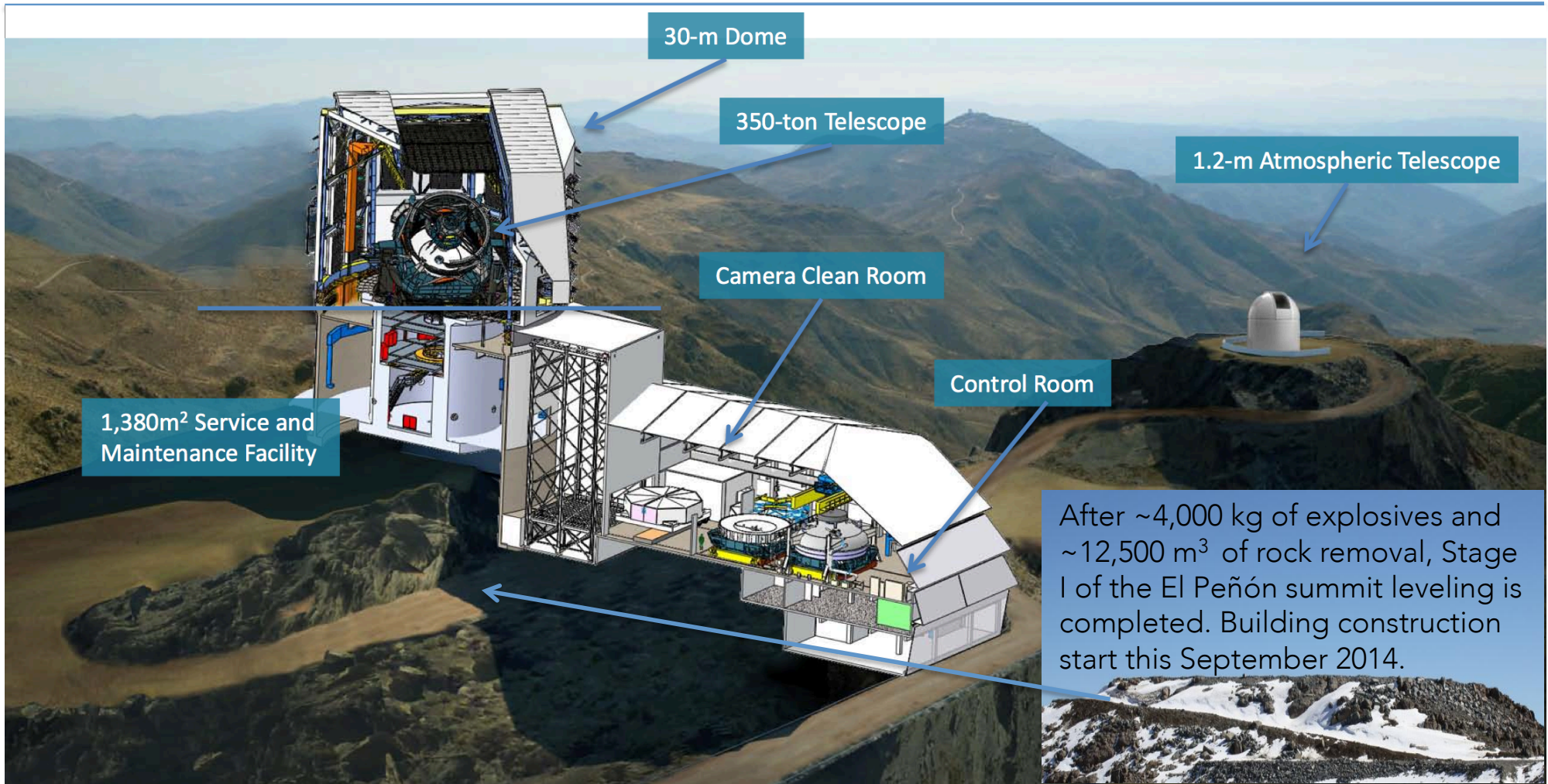
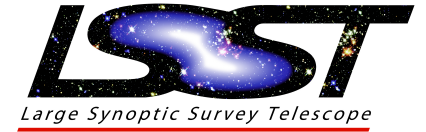
Catalog of 20 billions objects (10 galaxies, 10 stars) = 15 PB

LSST Status



- LSST ranked as the highest priority large ground-based facility for the next decade ([Astro10 , August 2010](#))
- Following this recommendation, NSF and DOE went ahead : LSST passed its [final design review \(NSF\) last year \(Dec. 2013\)](#) allowing the [construction to start in 2014](#).
- LSST will federate a community of ~ [900 scientists](#) over the world ([50% from US](#)) :
 - Except for France (in kind contribution) , integration of non-US scientist in LSST , will be associated to a fee of 200 000 \$ / PI : the goal is to cover ~30% of the LSST running cost
 - In Europe (most of it still under discussion) :
 - France : 130 – 150 PI
 - UK : ~ 100 – 180 PI (200 UK's scientists declared interest today)
 - Czechy, Croatia , Hungary , Poland, Serbia,... : ~ 50 PI

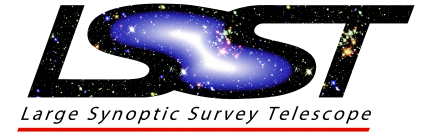
LSST Status – News (1/2)



Atmospheric telescope goals :

- Get the atmospheric transmission in real time toward LSST pointing
- Spectrometry or photometry of bright stars to build a model of atmospheric transmission

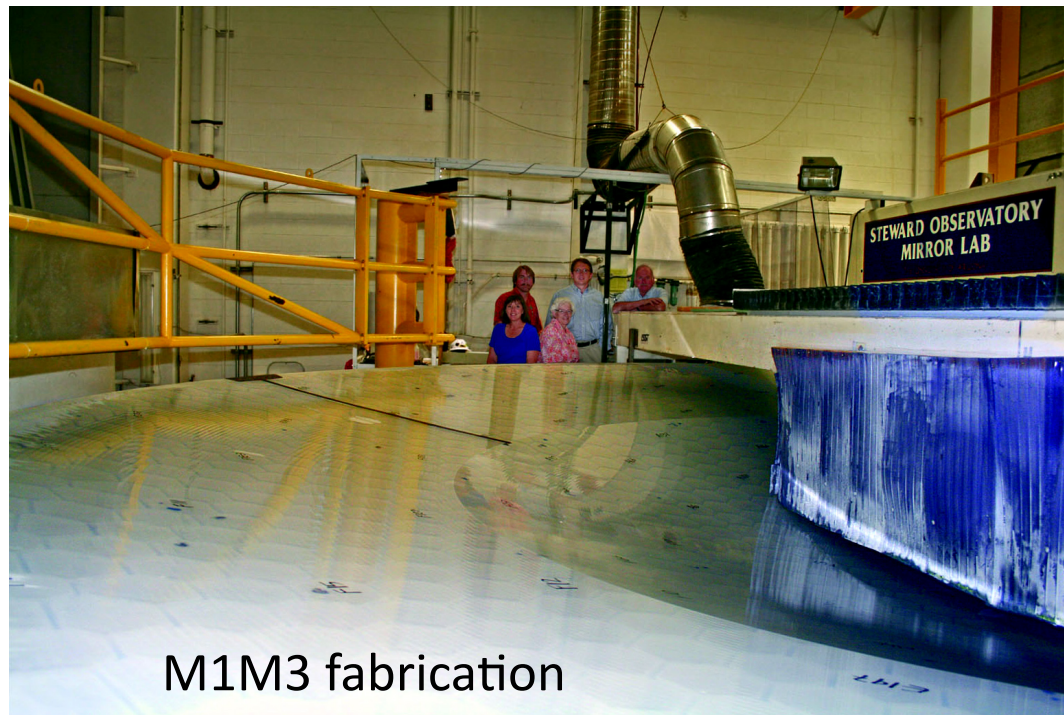
LSST Status – News (2/2)



Project is moving from R&D to construction at all level (coordination , hardware , ..)

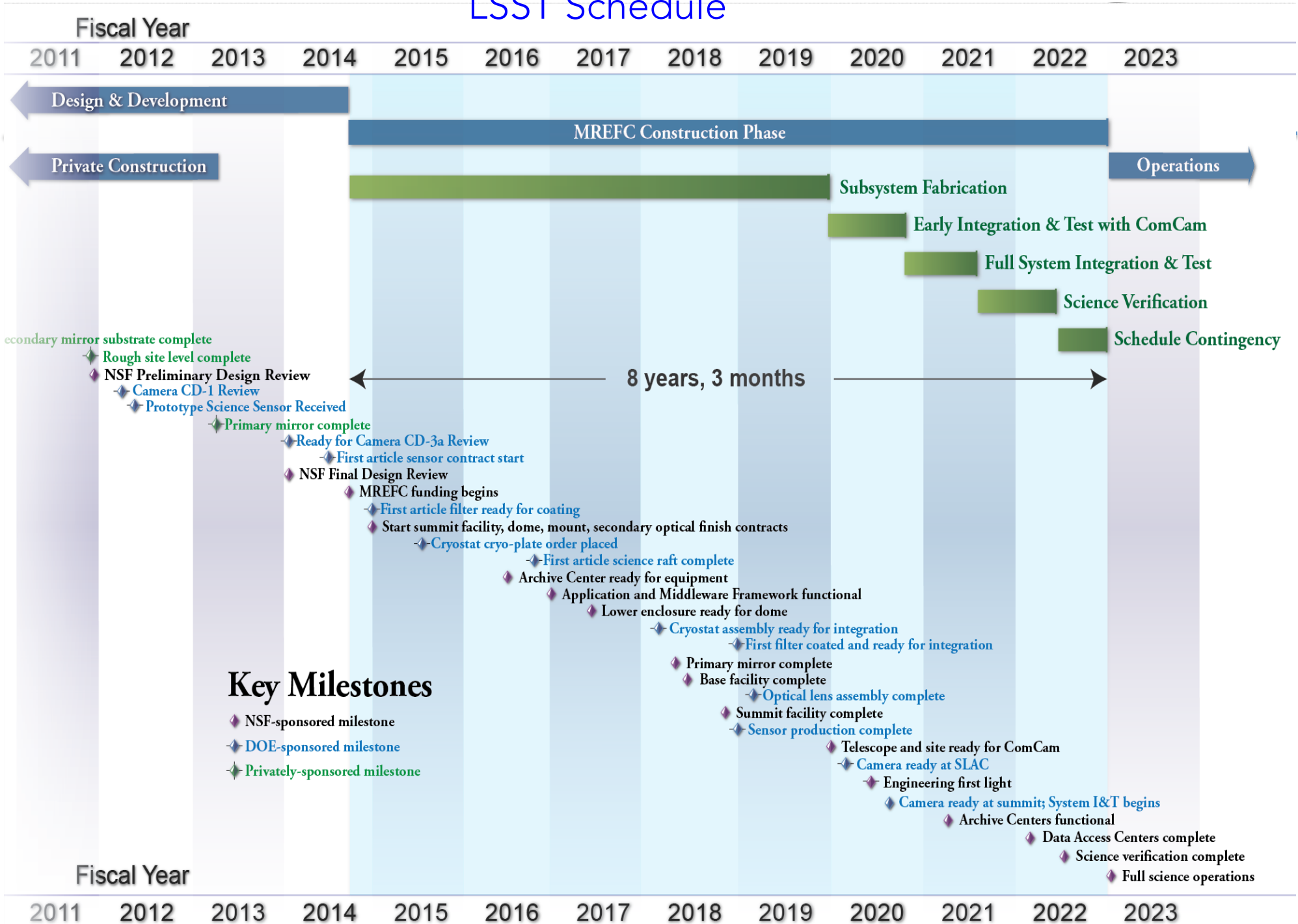
Two examples :

- End of sensor R&D : fully operational sensors received and tested , they fulfill all the key requirements: format, flatness , noise & sensitivity.
- Prototype of the CCD readout chain operational , including dedicated ASICs for CCD control and readout developed at IN2P3 , LAL & LPNHE ,(in-cryostat electronic , 3 10^9 pixels read in 2s)

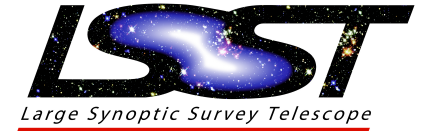


M1M3 fabrication

LSST Schedule



Science with LSST



4 major themes

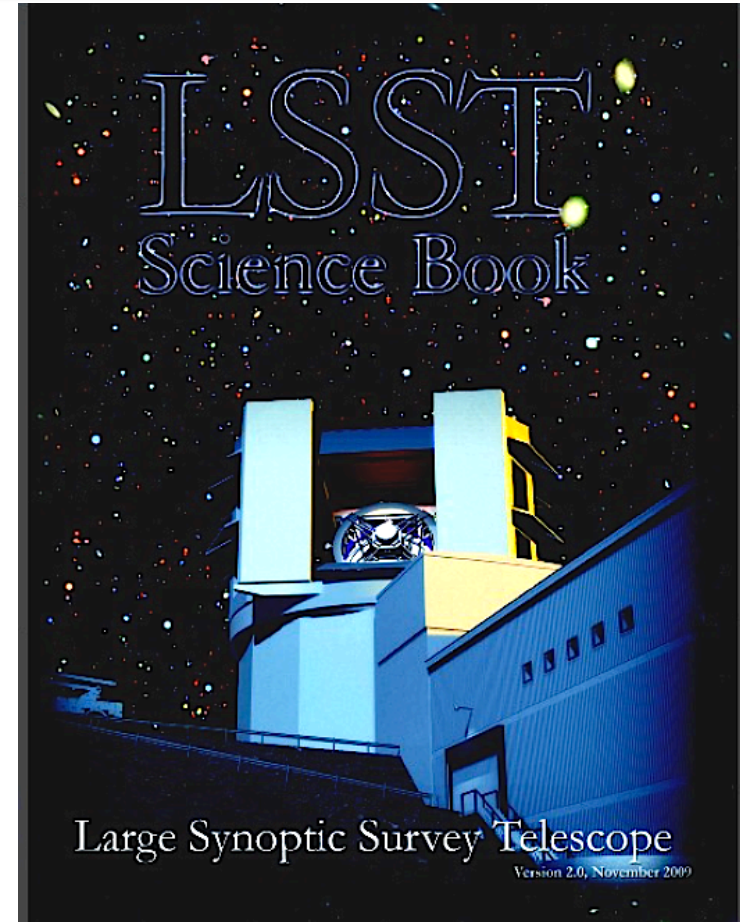
- Solar system
- Transient optical sky
- Mapping Milky Way
- Dark Energy, Dark matter

11 science collaborations

- Informatics and statistics
- Solar system
- Transient/variable stars
- Stellar populations
- Milky Way
- AGN
- Galaxies
- **BAO**
- **Clusters**
- **Supernovae**
- **Weak Lensing**



arXiv 1211.0310

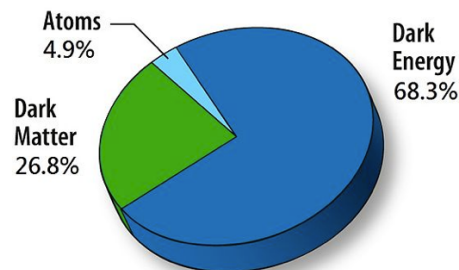
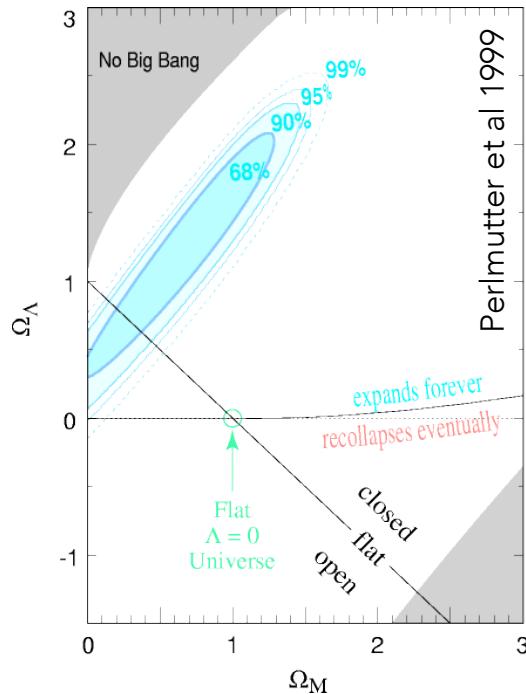


arXiv:0912.0201

In 2012 DOE urged LSST to set up a collaboration "à la" High Energy Physics on Dark Energy : DESC

The Dark Side of the Force

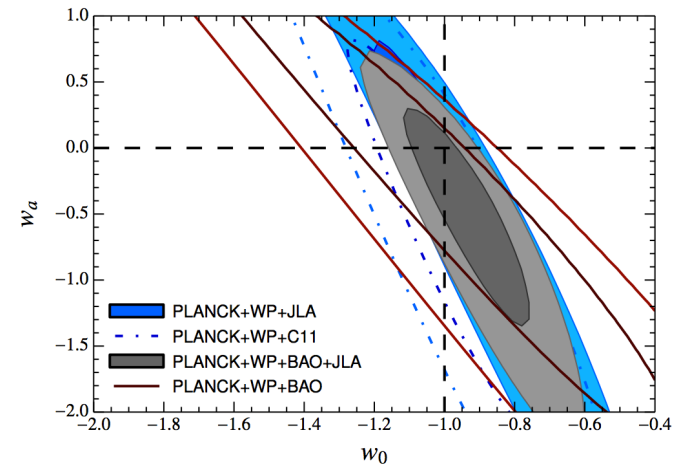
1999 smoking gun of the Universe acceleration



Planck 2013

Challenge to our understanding of fundamental physical laws and the nature of the cosmos

Dark Energy equation of state
 $P = [w_0 + w_a (1 - a)] \rho$

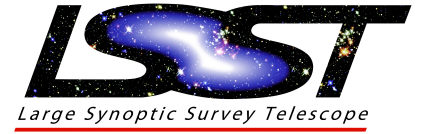


- Cosmological constant : $w = w_0 = -1$
- Some kind of dynamical fluid (quintessence ...)
 $w = w(a)$ and w_a is model-dependent
- Modification of general relativity

No persuasive theory: focus on observations

- Measure time (z) evolution : $w(a)$
- Cosmic expansion vs growth of structures

Probing Dark Energy



Measure the expansion history of the Universe and the growth of structures to test both geometrical and dynamical aspects of cosmological model

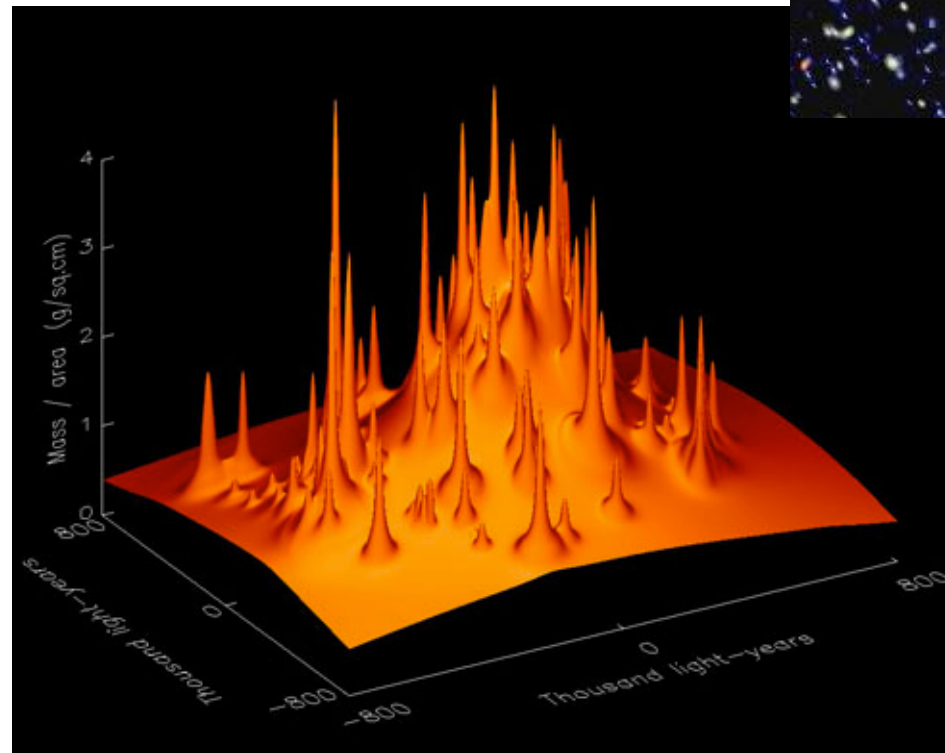
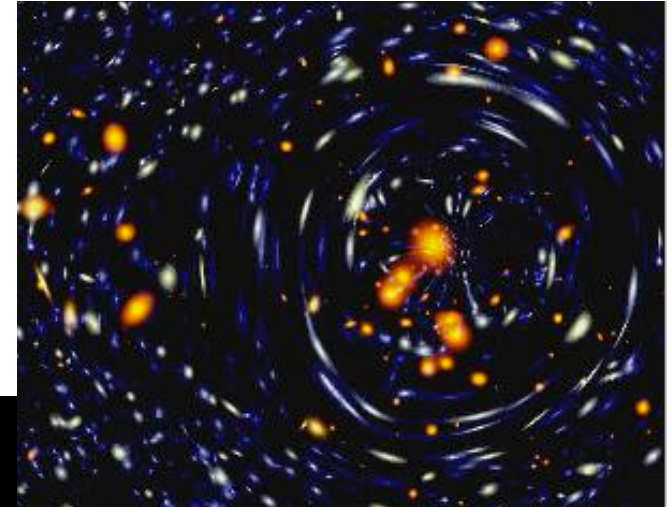
- BAO : standard ruler vs redshift (see Adeline's talk)
- Clusters : distribution vs redshift + growth rate of structures
- Supernovae (Ia) : luminosity distance vs redshift
- Weak lensing : angular distance vs redshift + growth rate of structures

+ CMB

Clusters

Study the clusters distribution to constraint dark energy (power spectrum)

Dark Matter distribution in cluster through background galaxy lensed observation



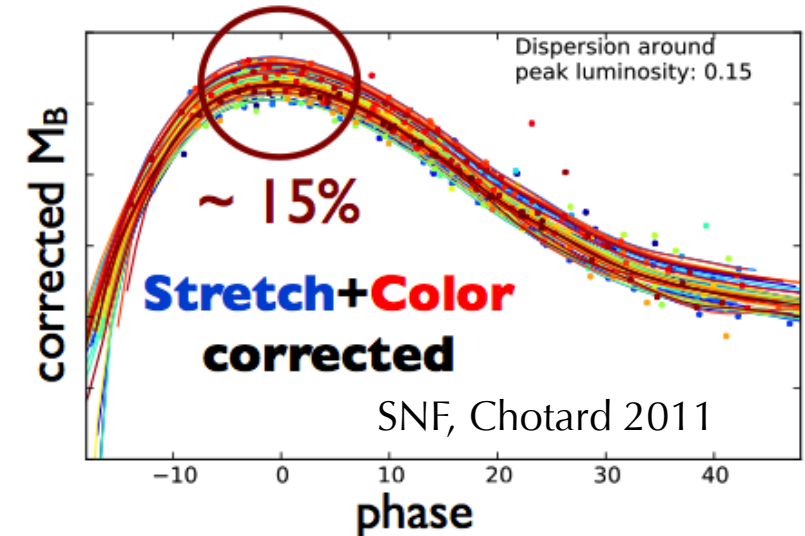
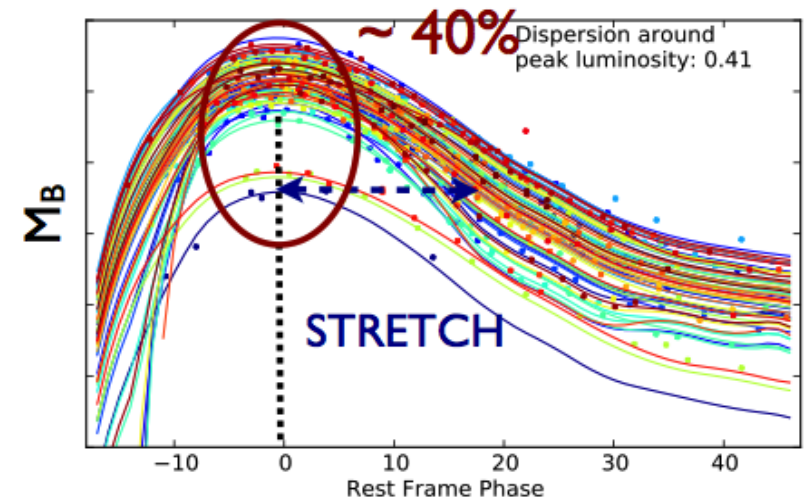
SN Ia

- First evidence for accelerating universe
 - Luminous $M_B \sim -19.3$ (Sun -27 Moon -13)
 - SN Ia best standard candles at large distance
- > Corrections needed :

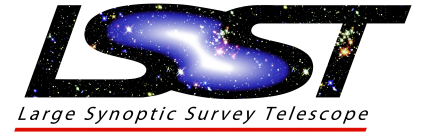
Extrinsic (IGM) : color correction

Intrinsic: stretch

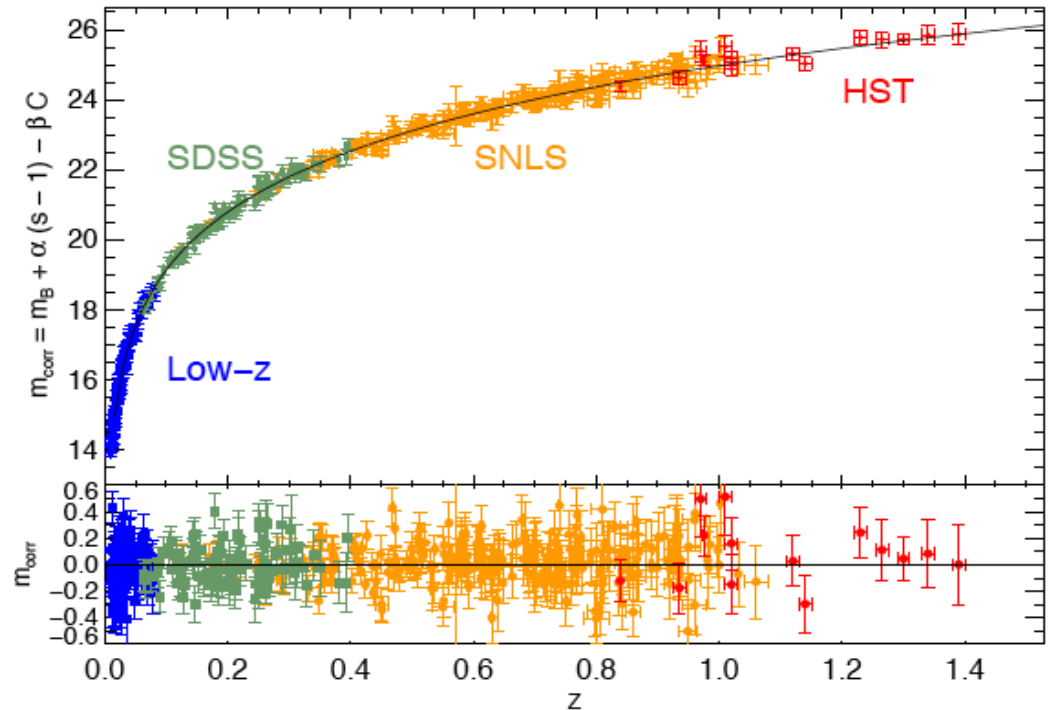
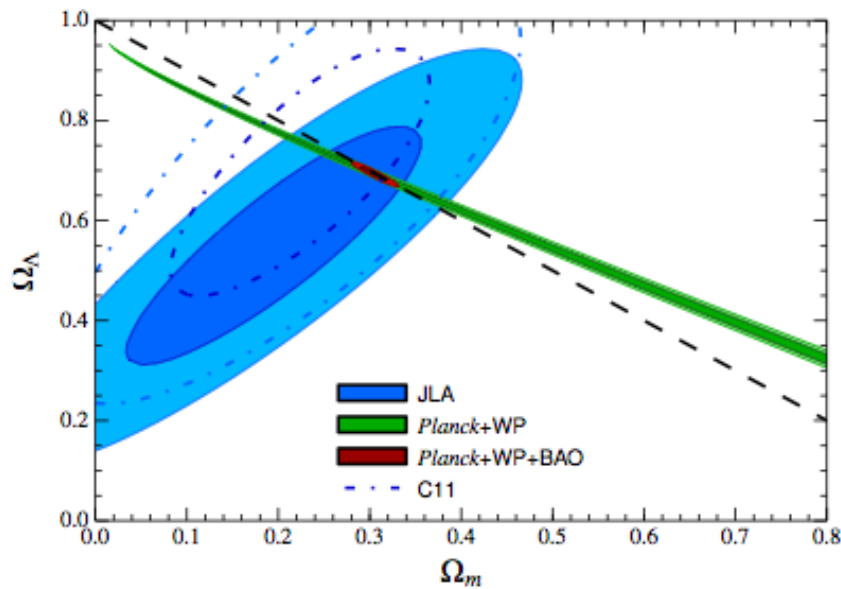
15% error (10% on distance) 2 parameters model can be improved



SN Ia current results



Bétoile 2014 : 720 SNIa
 Joint Light-Curve Analysis

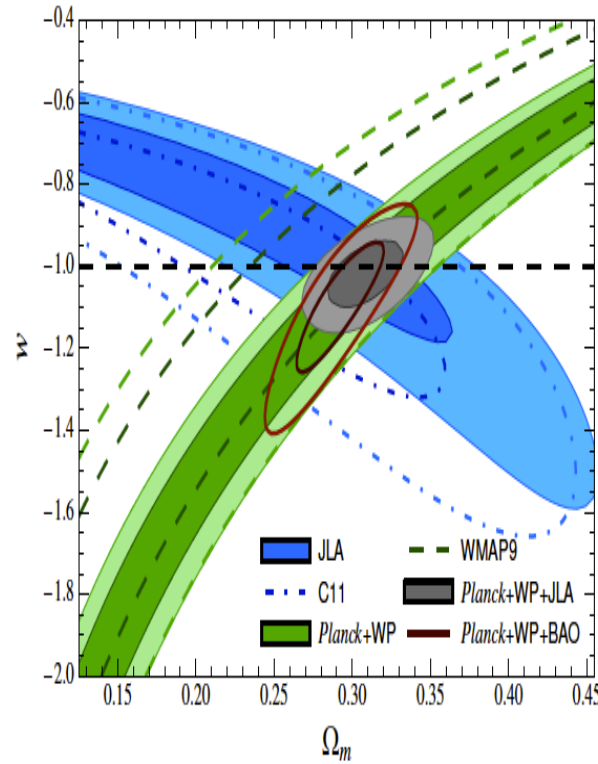
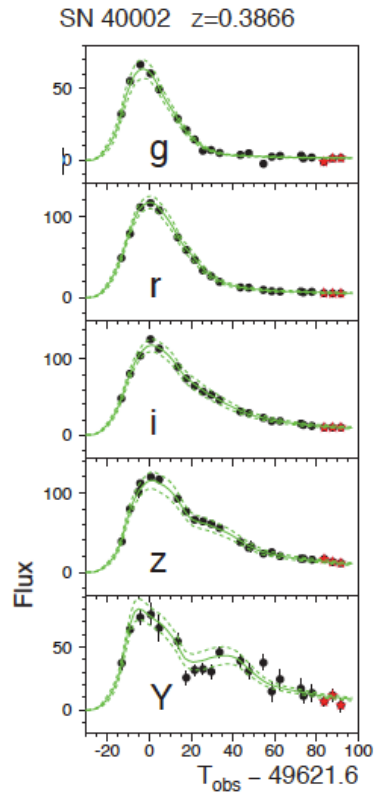


Errors :

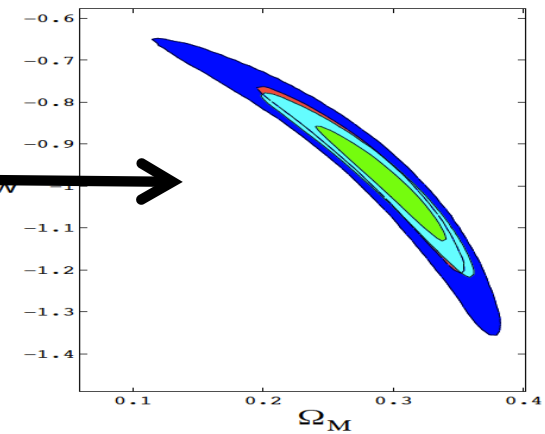
- Stat: 0.018 → negligible with LSST (millions of SN)
- Calibration: 0.20 → only 1 instrument to cover the whole range of z
- Other syst: 0.12 → the huge statistics will allow to improve M_B corrections (host type, mass, evolution ...)

SN Ia in LSST

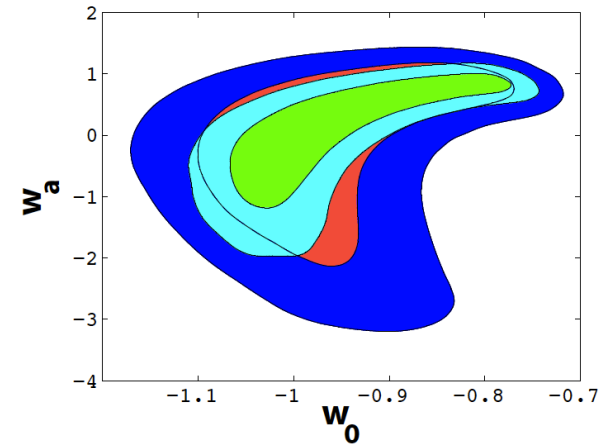
10,000 well measured SN / yr



LSST 10,000 SN

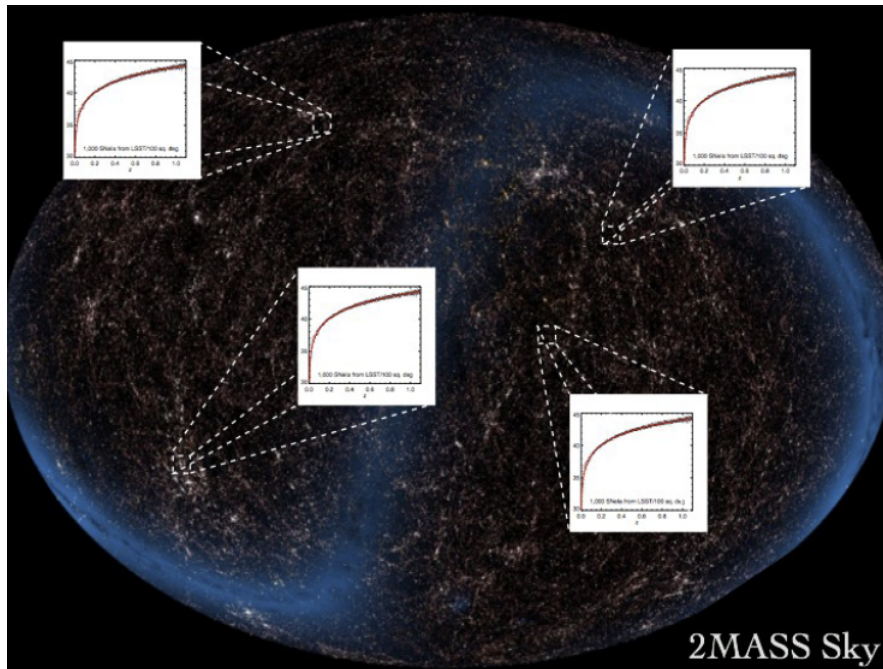


LSST 50,000 SN

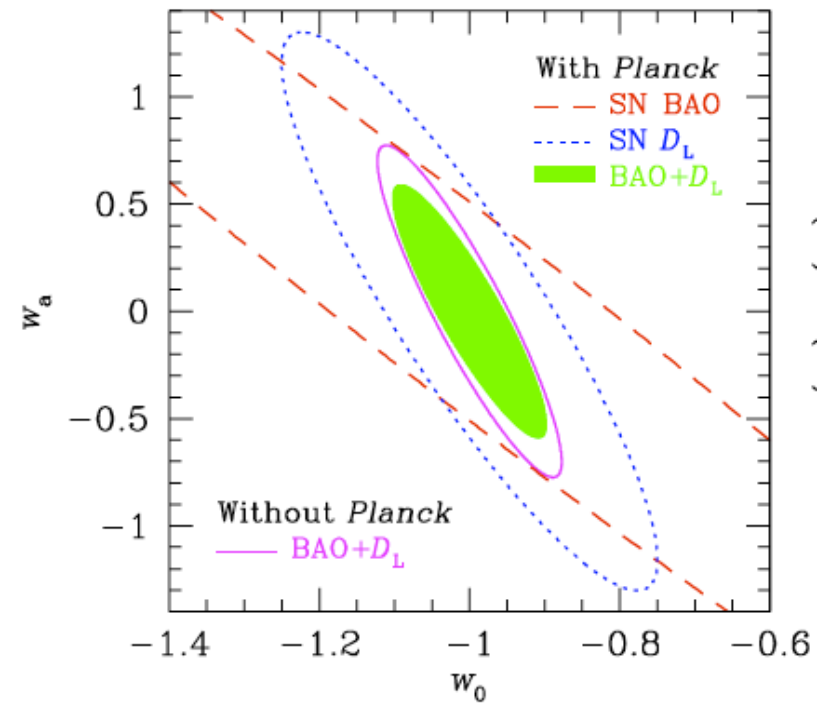


SN Ia in LSST

Massive set of SN : homogeneity, isotropy

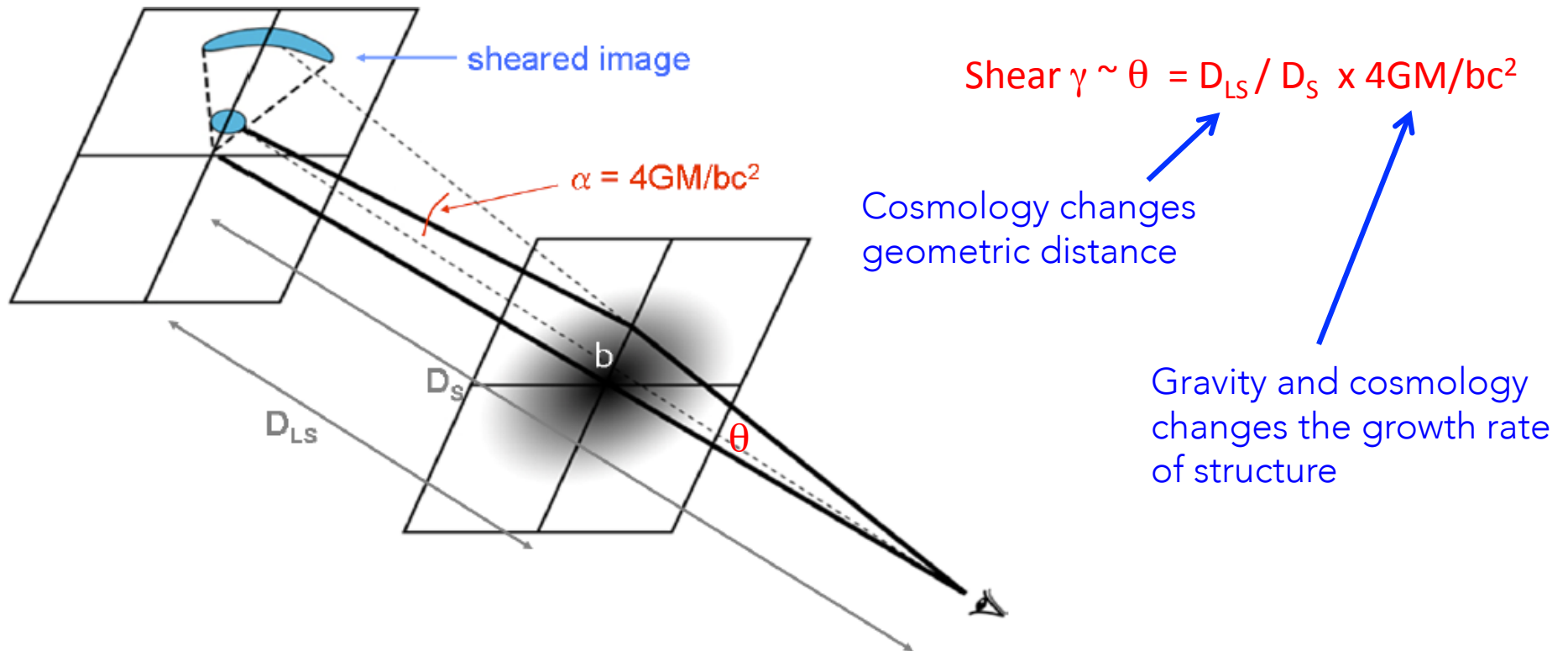


BAO with SN



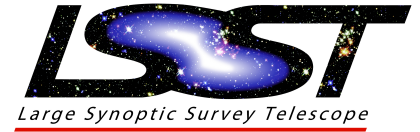
Weak Lensing

- Weak lensing (WL) is the most direct probe of the mass distribution in the Universe (not only the visible one)

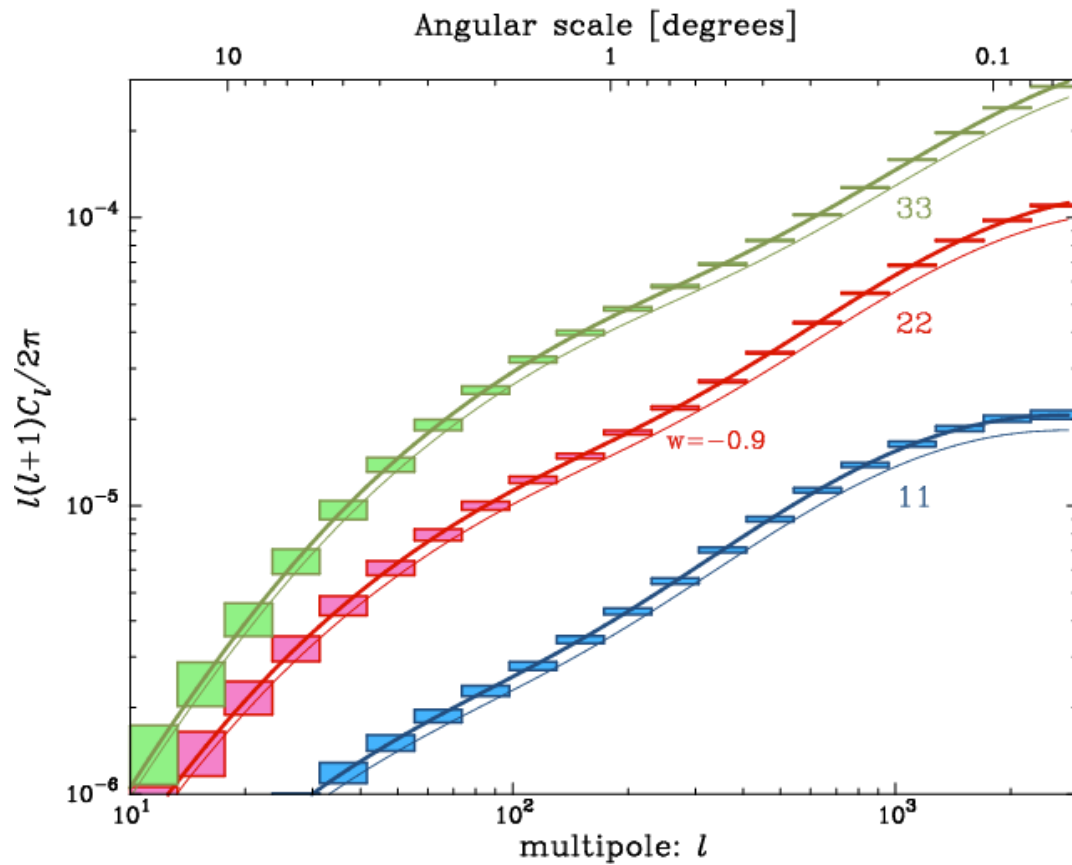


- Needs large statistical power (LSST speciality) and good angular resolution : only data in i and r (the most sensitive bands) for good observation conditions will be used for lensing

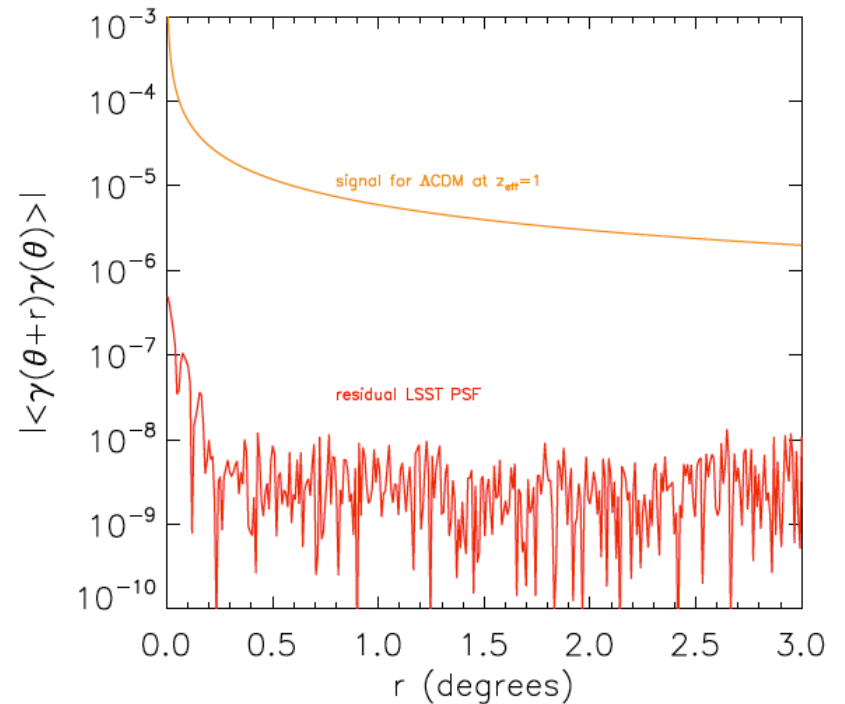
Weak Lensing in LSST



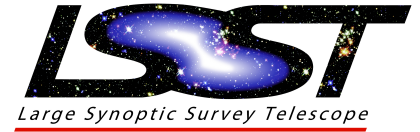
Lensing Power Spectra with 3 broad redshift bins
($z < 0.7$, $0.7 < z < 1.2$, $1.2 < z < 3$)



~ 100 visits will reduce
systematic shear correlation

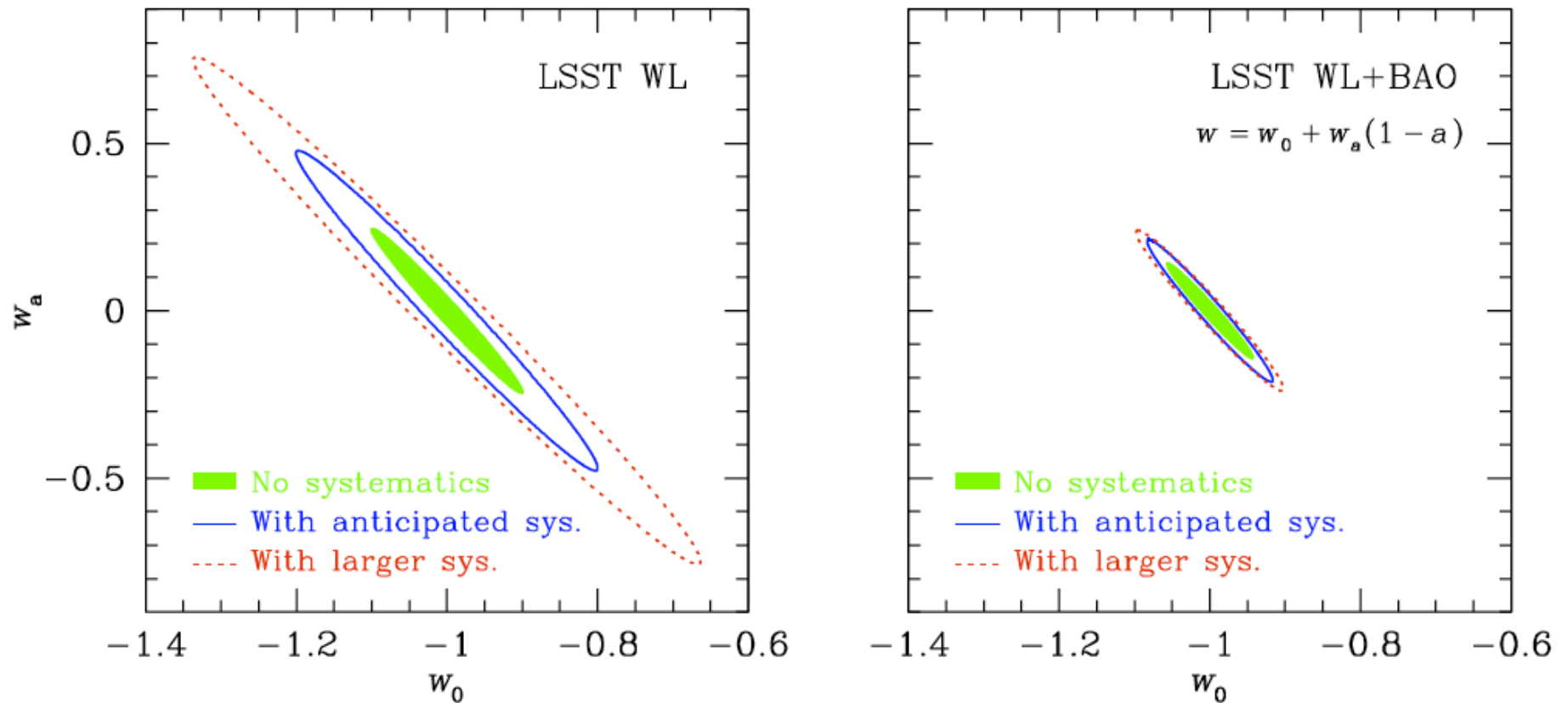


Probes combination is the key

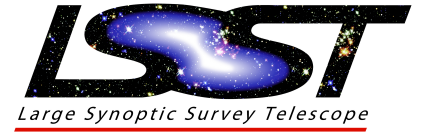


Combining WL + BAO break degeneracies

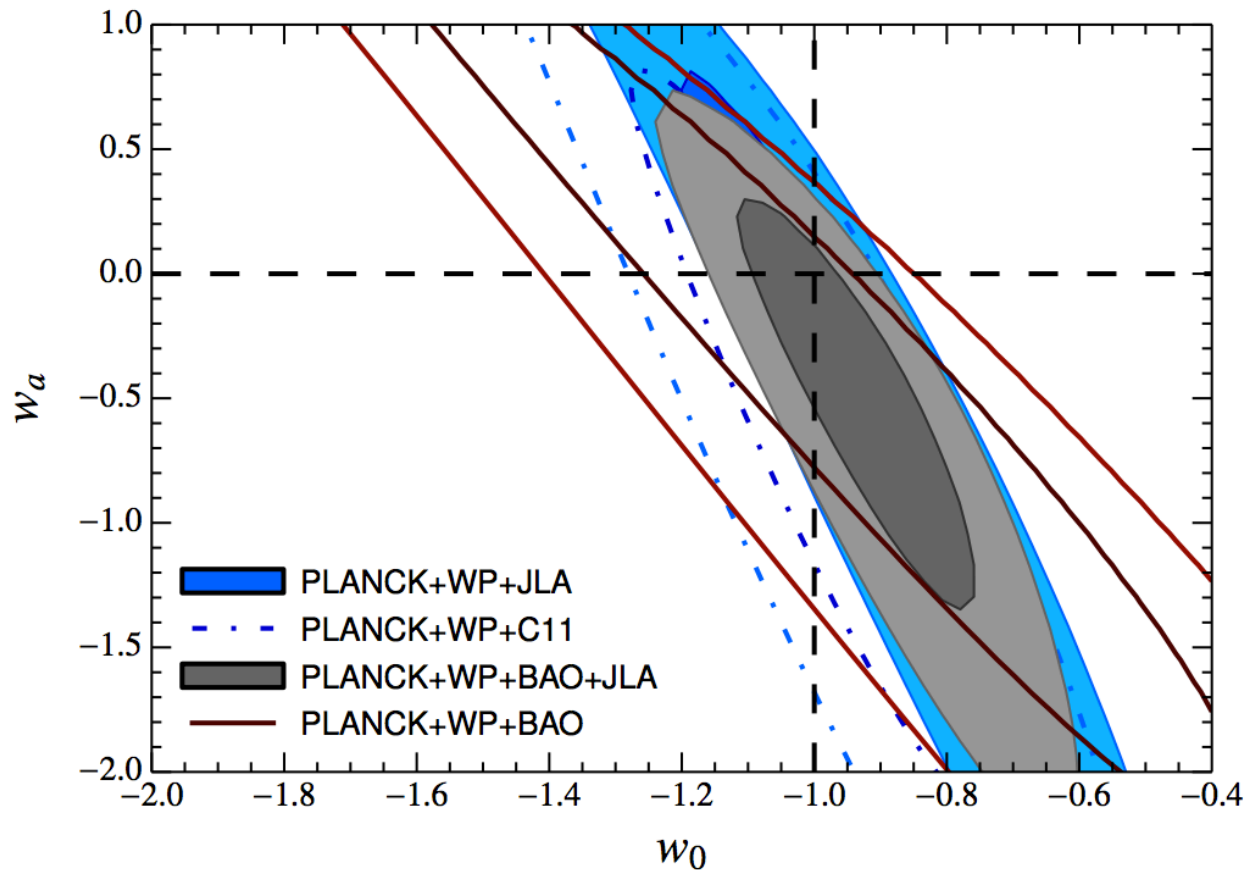
Combined analysis BAO + WL is less affected by systematics



LSST Dark Energy constraints



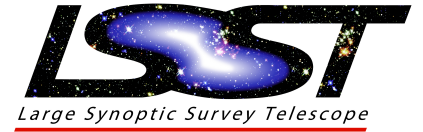
Multi-probes approach -> precise determination of equation of state



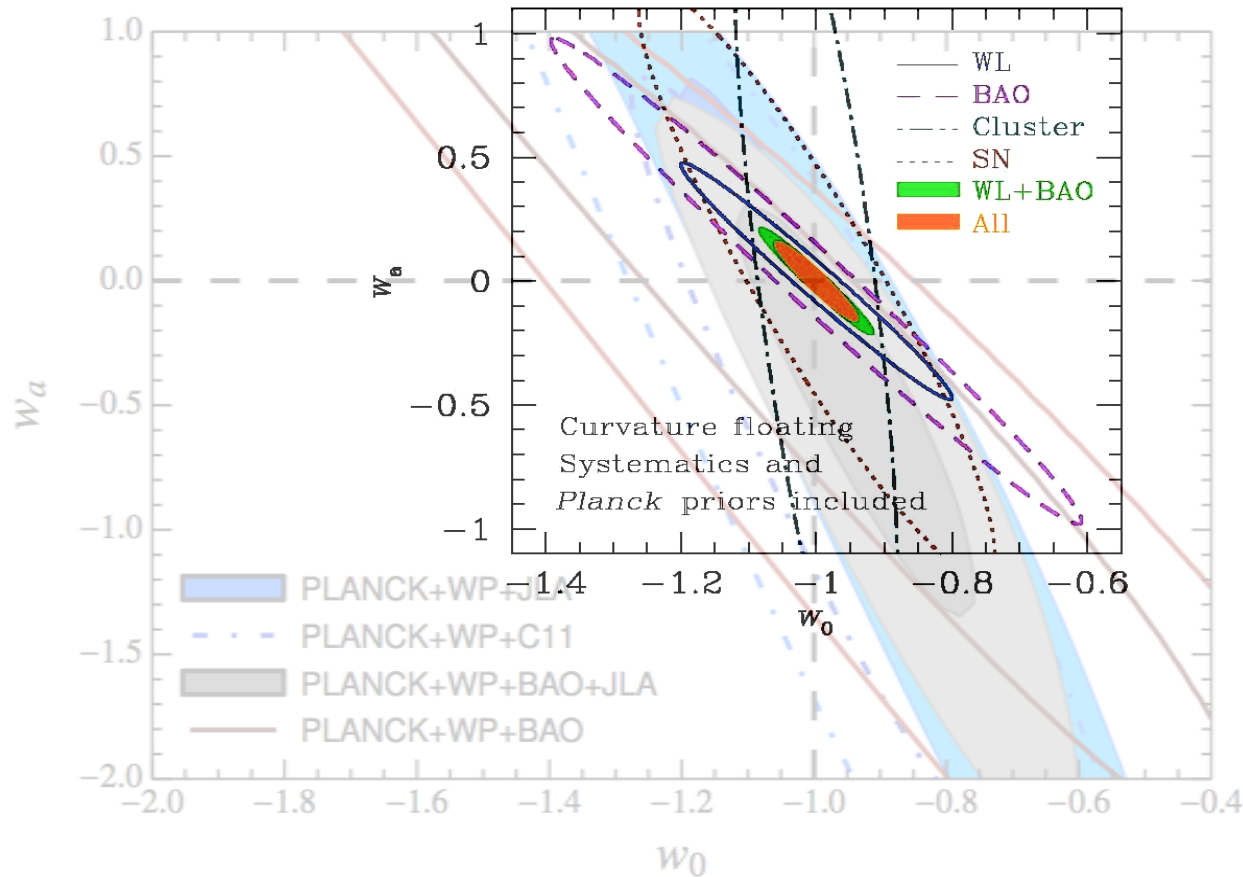
The huge statistics will allow to test DE (in)isotropy

Wide survey : measure DE in many patches over the sky

LSST Dark Energy constraints



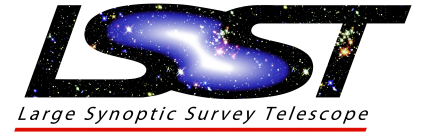
Multi-probes approach -> precise determination of equation of state



The huge statistics will allow to test DE (in)isotropy

Wide survey : measure DE in many patches over the sky

Conclusions



- Contraindre l'énergie noire est un des plus grand enjeux scientifique moderne pour notre compréhension de l'Univers
- LSST est un observatoire DE multi-sondes qui permettra d'atteindre une très bonne précision sur les paramètres de l'équation d'état
- Le succès de LSST vient également des nombreux autres domaines scientifiques qui y seront abordés : film 3D movie du ciel
- La collaboration DESC se met en place (meeting Philadelphia actuellement)
- La construction du télescope démarre maintenant
- Le succès de LSST dépend en grande partie du contrôle des systématiques, notamment la précision du photo-z (synergies Euclid) et donc de la bonne photométrie